

National Water Level Program Support Towards Building A Sustained Ocean Observing System For Climate

Allison Allen, Stephen Gill, Chris Zervas, Carolyn Lindley, and Lori Fenstermacher
NOAA National Ocean Service, Silver Spring MD

1. PROJECT SUMMARY

The objective of this project by the NOAA National Ocean Service (NOS) Center for Operation Oceanographic Products and Services (CO-OPS) is to develop and implement a routine annual sea level and extreme event analysis reporting capability that meets the requirements of the Climate Observation Program

The fundamental URL's are:

<http://tidesandcurrents.noaa.gov> for access to all programs, raw and verified data products, standards and procedures, and data analysis reports and special reports.

<http://opendap.co-ops.nos.noaa.gov/content/> for access to data through an IOOS web portal.

<http://tidesandcurrents.noaa.gov/slrends/slrends.shtml> for access to the latest NWLON sea level trends and monthly mean sea level anomalies.

http://tidesandcurrents.noaa.gov/slrends/slrends_global.shtml for access to the latest sea level trends and monthly mean sea level anomalies for a set of global sea level reference stations.

The Climate Operating Monitoring Principles employed by the Climate Program Office are very similar to those used by NOAA's National Water Level Program (NWLP). NWLP's backbone observation system is the National Water Level Observation Network (NWLON) is a long-term continuous operational oceanographic network which meets several of NOAA's mission needs for tides and water levels. The NWLP is an end-to-end program that is planned, managed, and operated to provide products that meet user-driven needs. The program is also comprised of continuous quality control, data base management, operational readiness, continuous developments in technology, and fully open web-site for data delivery. These data and associated sea level products are made available over the web-site for use by PSMSL, UHSLC, and the WOCE communities. \$100k was provided in last year's (FY2008) budget request to accomplish the task described below.

Task One - Routine Sea Level Analysis Reports

62 water level stations were identified in the International Sea Level Workshop Report (1997) as a core global subset for long-term sea level trends. The Climate Observations Program Plan calls these climate "reference stations" and includes the following performance measures for the reference stations:

1. Routinely deliver an annual report of the variations in relative annual mean sea level for the

entire length of the instrumental record.

2. Routinely deliver an annual report of the monthly mean sea level trend for the past 100 years with 95% confidence interval.

The CO-OPS technical report on sea level trends (Zervas, 2001) has been used as a starting template for an annual report. In addition to the analysis of long-term sea level trends and monthly mean sea level analyses, a new product is being developed to present summaries of the exceedance probabilities at selected stations.

In 2006, CO-OPS completed the development component of the routine analyses of the aforementioned 62 reference stations, including 18 NWLON stations and 44 non-NOAA global stations. The monthly mean sea level data for the non-NOAA stations were obtained from the Permanent Service for Mean Sea Level (PSMSL) website. The data set obtained was their Revised Local Reference (RLR) data which has been carefully quality-controlled for datum continuity.

http://tidesandcurrents.noaa.gov/slrends/slrends_global.shtml

The screenshot shows a web browser window with the URL http://tidesandcurrents.noaa.gov/slrends/slrends_global.shtml. The page title is "Sea Levels Online - Station Selection". The main content area is titled "Mean Sea Level Trends for Global Network Stations". It contains two tables: "CO-OPS Data" and "PSMSL Data". The CO-OPS Data table lists 18 stations: Honolulu, Hawaii; Guam, Marianas Is.; Kwajalein, Marshall Is.; Bermuda; Portland, Maine; Boston, Massachusetts; The Battery, New York; Atlantic City, New Jersey; Sewells Point, Virginia; Charleston, South Carolina; Fernandina Beach, Florida; and Key West, Florida. The PSMSL Data table lists 17 stations: Reykjavik, Iceland; Narvik, Norway; Bergen, Norway; Goteborg, Sweden; Stockholm, Sweden; Helsinki, Finland; Daugavgriva, Latvia; Liepaja, Latvia; Wismar, Germany; Esbjerg, Denmark; Cuxhaven, Germany; and Aberdeen, UK. Below the tables, a note states: "Water level records are a combination of the fluctuations of the ocean and the vertical land motion at the location of the station. The sea level variations determined are the linear trend, the average seasonal cycle, and the interannual variability at each station. All the calculated trends are also available as a table in [millimeters/year](#) or [feet/century](#)". At the bottom, there are links for "Station Location Maps" and "Information on presently operational CO-OPS stations". On the left sidebar, there is a list of "sea level trends" for various US states and "Global Stations".

Figure 1. The NOAA web-site for viewing information on sea level trends and monthly mean sea level anomalies at global tide stations.

The following example for the international stations follows the presentation template using all available PSMSL RLR data for each station:

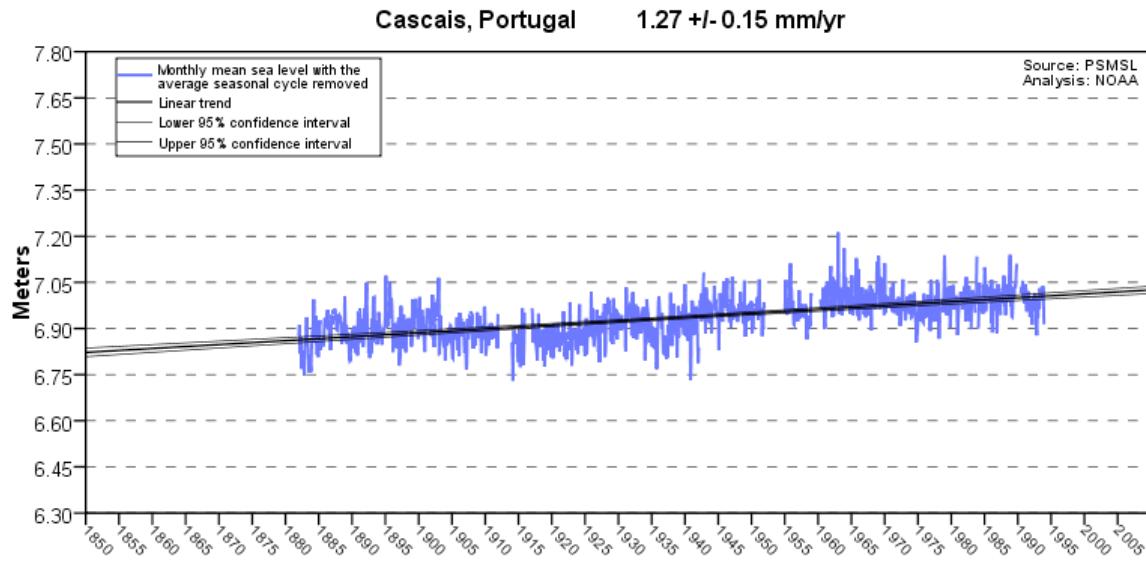


Figure 2. The sea level trend analysis.

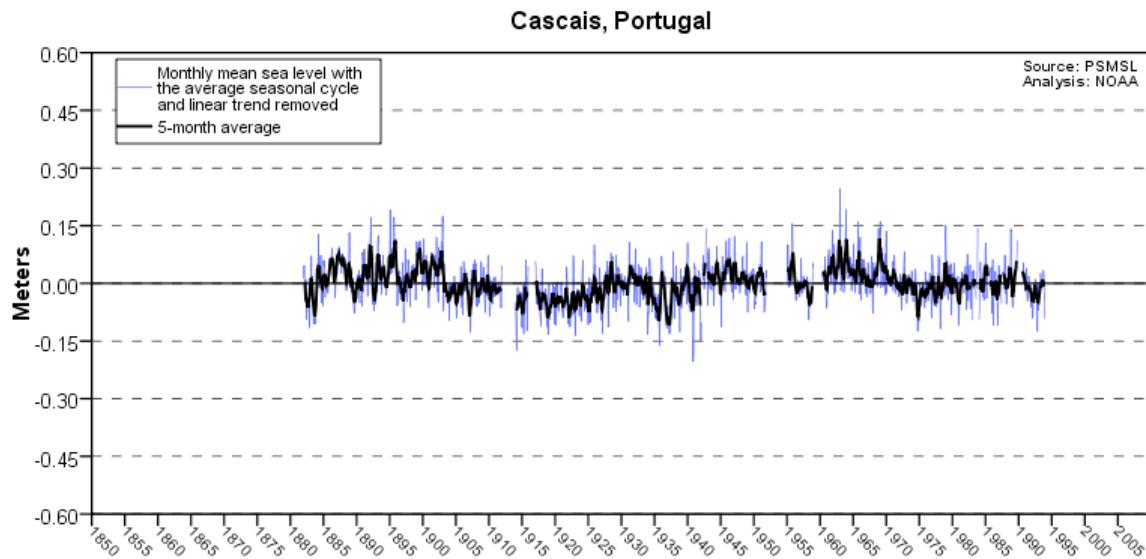


Figure 3. The interannual variation analysis.

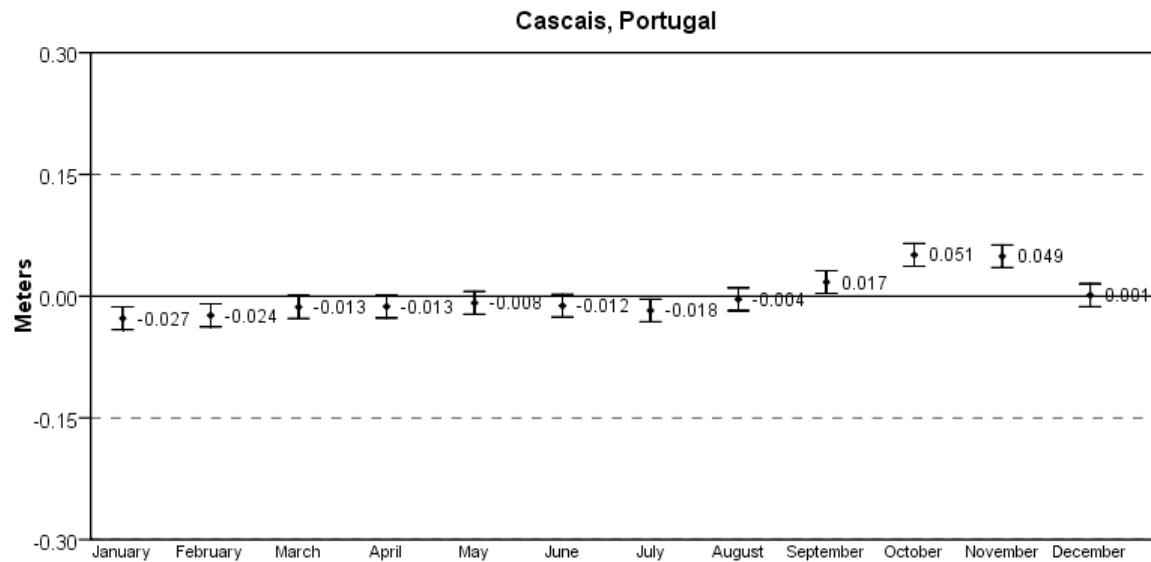


Figure 4. The average seasonal cycle analysis.

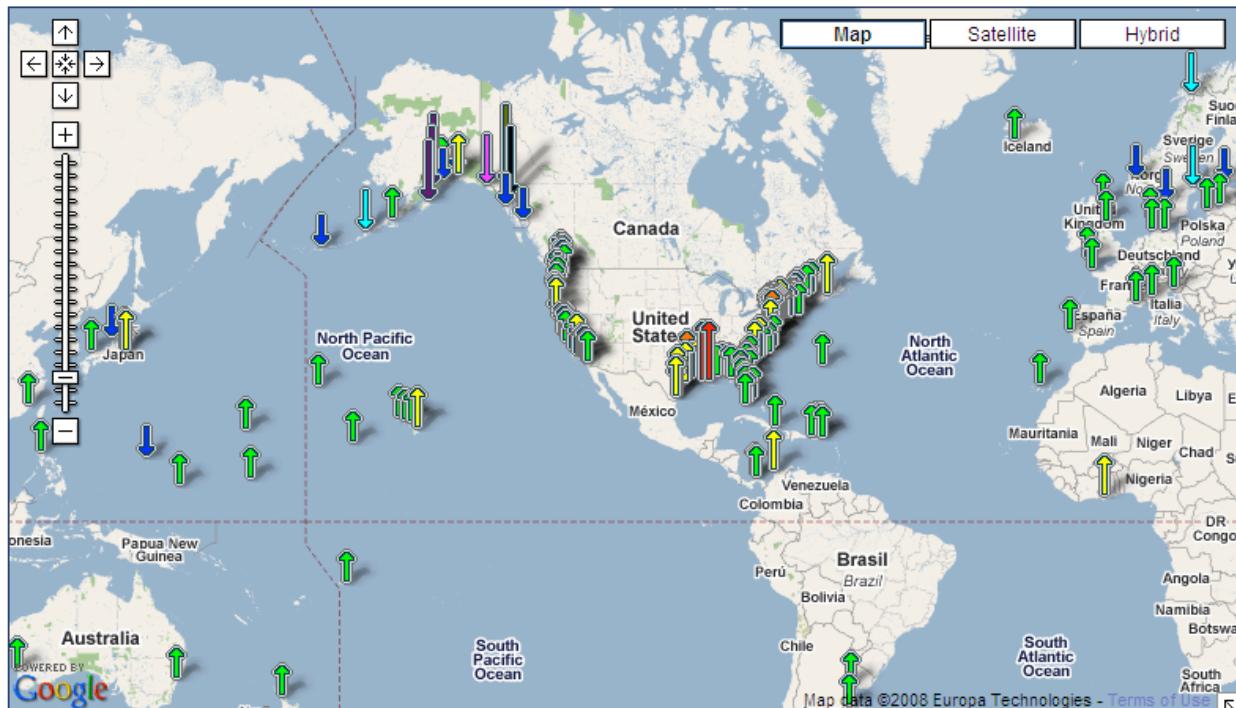


Figure 5. New Google map interface for Relative Sea Level Trends.

2. ACCOMPLISHMENTS

Efforts in FY2008 concentrated on getting the monthly sea level data compiled in a timely manner and generating routine reports established in the first year effort. These efforts have been coordinated with PSMSL, GLOSS and UHSLC programs.

In FY2008, linear sea level trends were recalculated for all NWLON stations with trends published in the previous NOAA Technical Report (Zervas, 2001), as well as analyses of 12 additional U.S. stations using all available data up to the end of 2006. The Sea Levels Online website was redesigned and a new Google Map interface was introduced to provide easier access for users to water level stations in their region of interest.

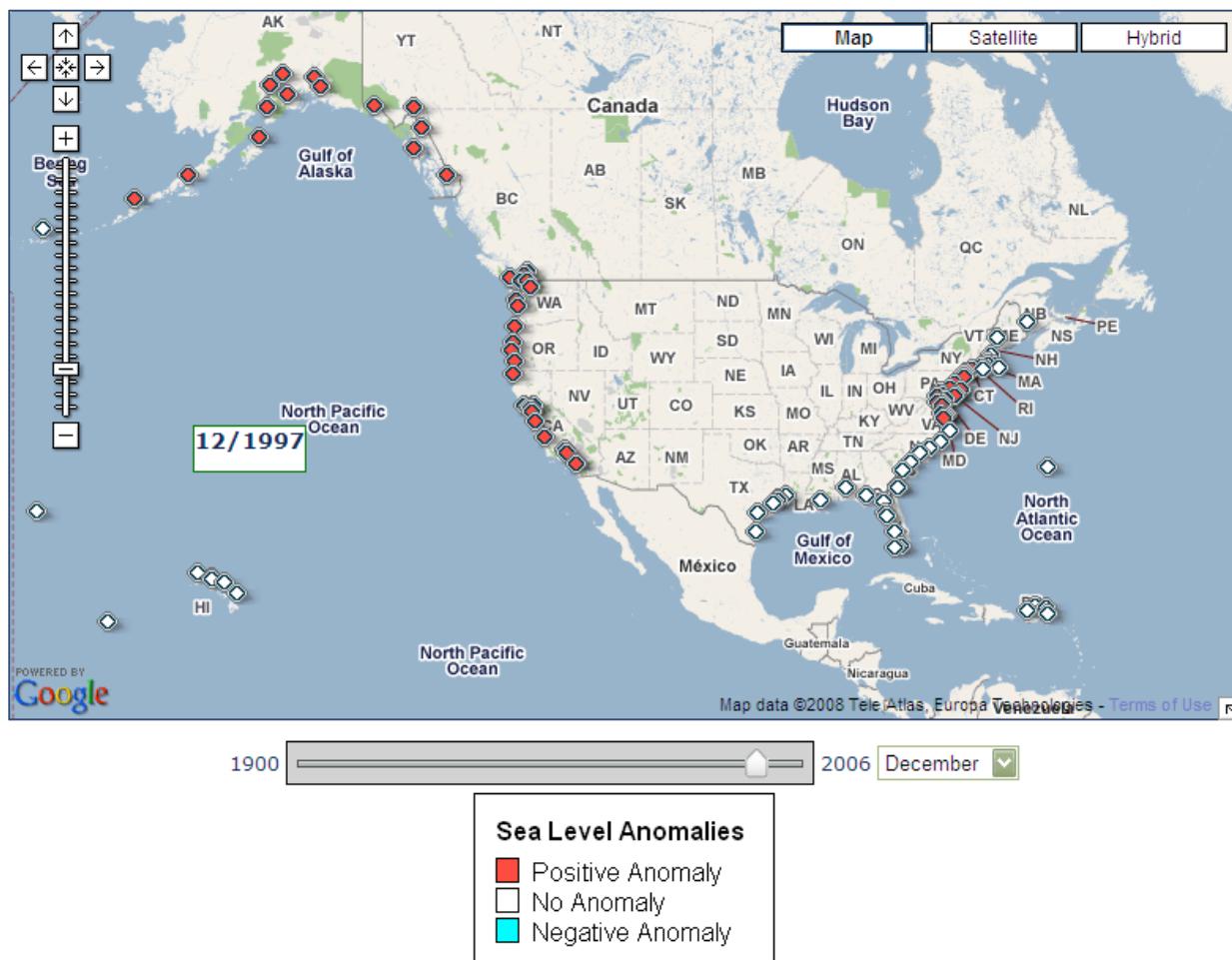


Figure 6. New Google map interface for Sea Level Anomalies (shown for December 1997).

CO-OPS has now extended the compilation of the data and the reports from the 62 global reference stations to nearly all of the 182 stations identified in Annex IV of the Global Sea Level Observing System (GLOSS) Implementation Plan 1997 (IOC Technical Series No. 50) (<http://unesdoc.unesco.org/images/0011/001126/112650eo.pdf>) as GLOSS-LTT (Long Term Trend). 45 of the GLOSS-LTT stations are CO-OPS stations and their sea level trends and variations were already available on Sea Levels Online.

A review of the PSMSL data available showed that a few of the GLOSS-LTT stations do not have enough data yet to obtain a reliable sea level trend. There are also a number of Scandinavian stations with long data sets that are no longer in operation; given the number of other stations in that region, these defunct stations were not analyzed. There are also a few river stations on the St. Lawrence River where sea level trends are not meaningful with respect to climate observations. The expanded global reference station network now consists of 159 stations, which means that a total of 97 stations have been added to the previous 62 climate reference stations.

Linear mean sea level (MSL) trends and 95% confidence intervals in mm/yr					
[Source of data: PSMSL and NOAA; Analysis: NOAA]					
Station Name	First Year	Last Year	Year Range	MSL Trend	95% Confidence Interval (+/-)
Reykjavik, Iceland	1956	2001	46	2.34	0.71
Barentsburg, Norway	1948	2006	59	-2.99	0.67
Murmansk, Russia	1952	2006	55	3.92	1.00
Narvik, Norway	1928	2001	74	-3.09	0.59
Heimsjo, Norway	1935	2006	72	-1.61	0.40
Maloy, Norway	1945	2006	62	0.93	0.52
Bergen, Norway	1883	2001	119	-0.52	0.23
Stavanger, Norway	1881	2006	126	0.42	0.21
Oslo, Norway	1885	2006	122	-4.53	0.34
Smogen, Sweden	1911	2007	97	-1.92	0.27
Goteborg, Sweden	1887	2003	117	-1.30	0.36
Klagshamn, Sweden	1929	2007	79	0.53	0.48
Kungholmsfort, Sweden	1887	2007	121	0.00	0.27
Landsort, Sweden	1887	2007	121	-2.85	0.32
Stockholm, Sweden	1889	2003	115	-3.94	0.35
Ratan, Sweden	1892	2007	116	-7.75	0.41
Furugrund, Sweden	1916	2007	92	-8.17	0.61
Kemi, Finland	1920	2006	87	-7.01	0.67
Oulu/Uleaborg, Finland	1889	2006	118	-6.38	0.43
Raahe/Brahestad, Finland	1922	2006	85	-6.81	0.71
Pietarsaari/Jakobstad, Finland	1914	2006	93	-7.32	0.61
Vaasa/Vasa, Finland	1883	2006	124	-7.36	0.36
Kaskinen/Kasko, Finland	1926	2006	81	-6.54	0.73
Mantyluoto, Finland	1910	2006	97	-5.96	0.53
Turku/Abo, Finland	1922	2006	85	-3.71	0.66
Degerby, Finland	1923	2006	84	-3.77	0.64
Hanko/Hango, Finland	1887	1997	111	-2.76	0.42
Helsinki, Finland	1879	2001	123	-2.41	0.37
Hamina, Finland	1928	2006	79	-1.03	0.85
Daugavgriva, Latvia	1872	1938	67	0.16	0.99
Liepaja, Latvia	1865	1936	72	0.88	0.72
Kaliningrad, Russia	1926	1986	61	1.84	0.89
Warnemunde, Germany	1855	2005	151	1.20	0.12
Wismar, Germany	1848	2003	156	1.38	0.10
Gedser, Denmark	1898	2006	109	0.94	0.19
Kobenhavn, Denmark	1889	2006	118	0.49	0.21
Hornbaek, Denmark	1898	2006	109	0.25	0.23

Linear mean sea level (MSL) trends and 95% confidence intervals in mm/yr

[Source of data: PSMSL and NOAA; Analysis: NOAA]

Station Name	First Year	Last Year	Year Range	MSL Trend	95% Confidence Interval (+/-)
Korsor, Denmark	1897	2006	110	0.75	0.19
Slipshavn, Denmark	1896	2006	111	0.93	0.17
Fredericia, Denmark	1889	2006	118	1.03	0.12
Aarhus, Denmark	1888	2006	119	0.56	0.12
Frederikshavn, Denmark	1894	2006	113	0.16	0.16
Hirtshals, Denmark	1892	2006	115	-0.20	0.22
Esbjerg, Denmark	1889	1997	109	1.05	0.31
Cuxhaven, Germany	1843	2002	160	2.44	0.17
Aberdeen, UK	1862	2003	142	0.66	0.10
North Shields, UK	1895	2003	109	1.88	0.16
Sheerness, UK	1832	2006	175	1.64	0.10
Newlyn, UK	1915	2003	89	1.71	0.20
Brest, France	1807	2000	194	1.00	0.08
La Coruna, Spain	1943	2006	64	1.31	0.47
Cascais, Portugal	1882	1993	112	1.27	0.15
Lagos, Portugal	1908	1999	92	1.50	0.24
Marseille, France	1885	2000	116	1.20	0.16
Genova, Italy	1884	1997	114	1.20	0.14
Trieste, Italy	1905	2001	97	1.15	0.22
Tuapse, Russia	1917	2002	86	2.24	0.65
Ponta Delgada, Portugal	1978	2005	28	2.55	1.09
Tenerife, Spain	1927	1999	73	1.53	0.31
Takoradi, Ghana	1929	1970	42	3.35	0.50
Walvis Bay, Namibia	1958	1998	41	0.33	1.44
Simons Bay, South Africa	1957	2007	51	1.59	0.28
Port Elizabeth, South Africa	1978	2007	30	3.13	1.40
Durban, South Africa	1971	2007	37	0.63	0.62
Aden, Yemen	1879	1969	91	1.23	0.20
Karachi, Pakistan	1916	1994	79	0.48	0.53
Mumbai/Bombay, India	1878	1994	117	0.74	0.12
Cochin, India	1939	2004	66	1.37	0.32
Chennai/Madras, India	1916	2003	88	0.31	0.41
Vishakhapatnam, India	1937	1996	60	0.54	0.52
Ko Taphao Noi, Thailand	1940	2006	67	0.49	1.06
Ko Lak, Thailand	1940	2002	63	-0.48	0.26
Macau, China	1925	1985	61	0.25	0.50
Xiamen, China	1954	2002	49	1.02	0.60
Yuzhno Kurilsk, Russia	1948	1994	47	2.74	0.62
Mera, Japan	1931	2001	71	3.66	0.24
Aburatsubo, Japan	1930	1999	70	3.33	0.27
Kushimoto, Japan	1957	2007	51	3.09	0.62
Hosojima, Japan	1930	2007	78	-0.53	0.32
Tonoura/Hamada, Japan	1894	2002	109	0.38	0.24
Wajima, Japan	1930	1999	70	-0.80	0.26
Manila, Philippines	1901	1969	69	1.78	0.35
Legaspi, Philippines	1947	2005	59	5.22	0.80
Davao, Philippines	1948	2005	58	5.32	1.30
Jolo, Philippines	1947	1996	50	0.19	1.12
Townsville, Australia	1959	2006	48	1.11	0.44

Linear mean sea level (MSL) trends and 95% confidence intervals in mm/yr					
[Source of data: PSMSL and NOAA; Analysis: NOAA]					
Station Name	First Year	Last Year	Year Range	MSL Trend	95% Confidence Interval (+/-)
Newcastle, Australia	1925	1988	64	2.19	0.48
Sydney, Australia	1886	2003	118	0.59	0.11
Fremantle, Australia	1897	2003	107	1.48	0.27
Auckland, New Zealand	1903	2000	98	1.29	0.20
Wellington, New Zealand	1944	2005	62	2.41	0.35
Lyttelton, New Zealand	1924	2000	77	2.36	0.29
Guam, Marianas Islands	1948	1993	46	-1.05	1.72
Chuuk, Caroline Islands	1947	1995	49	0.60	1.78
Kwajalein, Marshall Islands	1946	2006	61	1.43	0.81
Wake Island	1950	2006	57	1.91	0.59
Pago Pago, American Samoa	1948	2006	59	2.07	0.90
Midway Atoll	1947	2006	60	0.70	0.54
Johnston Atoll	1947	2003	57	0.75	0.56
Honolulu, USA	1905	2006	102	1.50	0.25
Hilo, USA	1927	2006	80	3.27	0.35
Adak Island, USA	1957	2006	50	-2.75	0.54
Seward, USA	1964	2006	43	-1.74	0.91
Sitka, USA	1924	2006	83	-2.05	0.32
Ketchikan, USA	1919	2006	88	-0.19	0.27
Prince Rupert, Canada	1909	2006	98	1.09	0.27
Vancouver, Canada	1910	1999	90	0.37	0.28
Victoria, Canada	1909	1999	91	0.80	0.25
Tofino, Canada	1909	2006	98	-1.59	0.32
Neah Bay, USA	1934	2006	73	-1.63	0.36
Friday Harbor, USA	1934	2006	73	1.13	0.33
Seattle, USA	1898	2006	109	2.06	0.17
Astoria, USA	1925	2006	82	-0.31	0.40
Crescent City, USA	1933	2006	74	-0.65	0.36
San Francisco, USA	1897	2006	110	2.01	0.21
Los Angeles, USA	1923	2006	84	0.83	0.27
La Jolla, USA	1924	2006	83	2.07	0.29
San Diego, USA	1906	2006	101	2.06	0.20
Balboa, Panama	1908	1996	89	1.38	0.27
Buenaventura, Colombia	1941	1969	29	0.96	1.22
La Libertad, Ecuador	1948	2003	56	-1.22	0.97
Antofagasta, Chile	1945	2006	62	-0.75	0.48
Puerto Deseado, Argentina	1970	2002	33	-0.06	1.93
Puerto Madryn, Argentina	1944	2000	57	1.50	0.79
Quequen, Argentina	1918	1982	65	0.85	0.31
Buenos Aires, Argentina	1905	1987	83	1.57	0.30
Montevideo, Uruguay	1938	1995	58	1.21	0.69
Cananeia, Brazil	1954	2006	53	4.20	0.63
Cartagena, Colombia	1949	1992	44	5.31	0.37
Cristobal, Panama	1909	1980	72	1.41	0.22
Galveston Pier 21, USA	1908	2006	99	6.39	0.28
Pensacola, USA	1923	2006	84	2.10	0.26
Key West, USA	1913	2006	94	2.24	0.16
Bermuda	1932	2006	75	2.04	0.47
Mayport, USA	1928	2006	79	2.40	0.31

Linear mean sea level (MSL) trends and 95% confidence intervals in mm/yr					
[Source of data: PSMSL and NOAA; Analysis: NOAA]					
Station Name	First Year	Last Year	Year Range	MSL Trend	95% Confidence Interval (+/-)
Fernandina Beach, USA	1897	2006	110	2.02	0.20
Fort Pulaski, USA	1935	2006	72	2.98	0.33
Charleston, USA	1921	2006	86	3.15	0.25
Wilmington, USA	1935	2006	72	2.07	0.40
Sewells Point, USA	1927	2006	80	4.44	0.27
Washington, USA	1924	2006	83	3.16	0.35
Annapolis, USA	1928	2006	79	3.44	0.23
Baltimore, USA	1902	2006	105	3.08	0.15
Philadelphia, USA	1900	2006	107	2.79	0.21
Atlantic City, USA	1911	2006	96	3.99	0.18
Sandy Hook, USA	1932	2006	75	3.90	0.25
The Battery, USA	1856	2006	151	2.77	0.09
Kings Point/Willets Point, USA	1931	2006	76	2.35	0.24
Newport, USA	1930	2006	77	2.58	0.19
Woods Hole, USA	1932	2006	75	2.61	0.20
Boston, USA	1921	2006	86	2.63	0.18
Portland, USA	1912	2006	95	1.82	0.17
Eastport, USA	1929	2006	78	2.00	0.21
Saint John, Canada	1914	1999	86	2.75	0.33
Halifax, Canada	1895	2002	108	3.16	0.15
Pointe-Au-Pere, Canada	1900	1983	84	-0.36	0.40
Quebec, Canada	1910	2006	97	-0.17	0.49
Neuville, Canada	1914	2006	93	0.17	0.79
Argentine Islands, Antarctica	1958	2006	49	1.72	0.49

3. PUBLICATIONS AND REPORTS

Results, analyses, and data products are routinely updated and reported on via the CO-OPS web site at: <http://tidesandcurrents.noaa.gov/slrends/slrends.html>.